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NBIC - Interdisciplinarity?

A Framework for a Critical Reflection
on Inter- and Transdisciplinarity of the NBIC-scenario

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NBIC-Interdisciplinarity ?

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Abstract: Interdisciplinarity is one of the most popular buzzwords used in contemporary *knowledge politics*. However, at the same time, the term is not well defined. In order to clarify its meaning, this paper classifies different kinds of interdisciplinarity. The aim is to show which specific kind of interdisciplinarity is involved in the NSF-NBIC-scenario on convergence technologies. It will be shown that the NBIC-scenario is based on a "realconstructivistic object-interdisciplinarity" that is the implicit basis for recent NBIC-knowledge politics. This type of interdisciplinarity will be explicated and contrasted with the research program of the European Union that widens the circle of convergence (*C*onverging *T*echnologies for the *E*uropean *K*nowledge *S*ociety/CTEKS; Initiative of the European Commission). It will be shown that the main difference between the two programs on convergent technologies is object-interdisciplinarity *on the one hand* and problem-oriented-interdisciplinarity *on the other hand*.

1. Introduction

Since Erich Jantsch's programmatic talk at a OECD-symposium in 1970 (Jantsch 1972), "interdisciplinarity" has become a popular term in knowledge politics and technoscientific rhetoric (Stehr 2001; Stehr 2005). Today, "interdisciplinarity" is everywhere and nowhere—the term has obviously lost its critical-reflexive power of the 1970s and remains just functionalistic (cp. Euler 1999). Late-modern "knowledge societies" (Böhme/Stehr 1986) seem to demand "interdisciplinarity" for knowledge production and processing, for competitiveness and customer care; "interdisciplinarity" is highly valued. The NBIC-visionaries advertise their approach by referring to "interdisciplinarity", namely the "integration" and "convergence" of nanotechnology, biotechnology, information technology and cognitive science (NBIC) (Roco/Bainbridge 2002). Here, interdisciplinarity should guarantee the "synergistic combination of four major 'NBIC'." The main question addressed in this paper is: Should we follow the visionaries and label the NBIC-vision "interdisciplinary", even if it turns out—as will be shown in this paper—that the vision is based on a strong *metaphysical* and *techno(onto)logical reductionism* that considers mainly technoscientific objects and neglects a critical societal reflection and revision?

This question is not easy to address. After more than thirty years of public and scientific debate, it is not clear at all what the popular buzzword "interdisciplinarity" means, although some clarification has been achieved.[1] One main cause for the lack of clarity is that philosophers and methodologists have remained reluctant to engage with this issue, even though it is interlaced with the fundamentals of philosophy. However, the aim of this paper is to demonstrate that a philosophical approach provides helpful guidelines to ana lytically disentangle the umbrella term "interdisciplinarity" and to critically clarify the kind of interdisciplinarity that is involved in the NBIC-scenario.

In the next section I will present some nebulous quotes from the original Roco-Bainbridge-report in which buzzwords such as interdisciplinarity, integration, convergence, unification, and reduction appear (sec. 2). My basic motivation is to provide a clarification. – Then, by referring to some well-established differences in philosophy of sciences, I will propose a classification scheme of four different types of interdisciplinarity (sec. 3): interdisciplinarity with regard to (a) objects / entities ("ontology"), (b) theories / knowledge (epistemology), (c) methods / practices (methodology), and further, (d) reflexive problem-perception / problem-solving. Different philosophical traditions can be related to these distinguishable meanings. – It will be shown that the NBIC-type can be classified as an object-interdisciplinarity that mainly refers to real-constructed (techno-) objects (sec. 4). Most interesting is here that the NBIC-kind of object-interdisciplinarity is based on strong *metaphysical* convictions (related to a belief in the unity of Nature) and it encompasses an *onto-(techno-)logical* reductionism (related to a belief that one can shape the world by shaping atoms). The identification of technoscientific development *on the one hand* and humane and societal progress *on the other hand* can be traced back to Francis Bacon's technological optimism (sec. 5). – Finally, the (techno-) object-interdisciplinarity of the NBIC-scenario will be compared and contrasted with the problem-oriented interdisciplinarity of the European-Commission initiative on converging technologies (CTEKS) (sect. 6).

Thus, "interdisciplinarity" in the NBIC-scenario is driven by strong, metaphysically laden, reductionist visions of new (techno-) objects. This kind of interdisciplinarity turns out to be an excellent example of contemporary knowledge politics (Stehr 2001; Stehr 2005);[2] a new field of political activity is emerging in late-modern "knowledge societies" (Böhme/Stehr 1986), aimed at fostering and regulating the research, development and use of new "interdisciplinary" technoscientific knowledge.

2. The NBIC-Scenario and Central Terms of the *NBIC-knowledge Politics*

The general direction of the U.S.-National Science Foundation (NSF)—to foster and to fund interdisciplinarity, integration and innovation of diverse engineering sciences—is comprehensible (Roco/Bainbridge 2002). Engineering sciences appear to be largely a diverse patchwork consisting of very different branches such as electrical, mechanical, material, civil, environmental, informational, biomechanical and biomedical engineering. Classical technologies are bounded technologies (Schmidt 2004) which are developed and applied in specific contexts, e.g. biomedical technologies in the field of medicine or information technologies in the context of information processing, management and storage.

Today, specialization has splintered engineering sciences and no one in any of the disciplines can master more than a tiny isolated fragment of all the technical problems. During the last 60 years, efforts have been made to bring together the various parts of science-based technologies, e.g., the earlier attempts of cybernetics in the 1940's, general systems theory, information theory, micro systems technology. But no overall progress has been made until now; engineering sciences still remain a patchwork. In fact, the boundaries between engineering sciences restrict the pace of invention and innovation.

> "The traditional tool kit of engineering methods will be of limited utility in some of the most important areas of technological convergence." (Roco/Bainbridge 2002, 11)

The NSF aims to overcome this apparent limitation by seeking a common technoscientific fundament underlying (or should underly) all the engineering sciences. *Technoscience* is a perfect term that highlights the merging of natural science, engineering sciences and tech nology (Latour 1987; Haraway 1995; Nordmann 2004). Such a deeper fundament should help to transgress the borders between the various engineering sciences and between engineering and natural sciences—and, thus, it should also foster inventions and innovations. The NBIC-vision can be understood—and this is my interpretation of the NSF-approach and the Roco-Bainbridge-report (2002)—as a *foundational attempt* for engineering sciences. In order to highlight the foundational aspect, the NSF-report speaks much about "enabling technologies" and less about "technologies" themselves. Enabling technologies are thought to be rooted at a deeper level: *enabling technologies are (basic and fundamental) technologies that enable, create and foster particular technologies in applied branches*.

According to the NSF, interdisciplinarity is a necessary condition to develop "enabling technologies", such as nanotechnology, biotechnology, information technology and cognitive sciences. Interdisciplinarity turns out to be a *functional* key element in the NBIC-vision to obtain a combination, convergence and unification of sciences. The NSF explicitly highlights the need for "Unifying Science and Converging Technologies"; their vision is to "Improve Human Performance" (Roco/Bainbridge 2002, x). Surprisingly, however, this vision seems to be rooted in the traditional metaphysical claim of a unity of nature that reveals a strong naturalism:

> "In the early decades of the 21st century, concentrated efforts can *unify science* based on the *unity of nature*, thereby advancing the combination of nanotechnology, biotechnology, information technology, and new technologies based on cognitive sciences." (ibid., ix; italic by J.C.S.)

Although the NSF-Roco-Bainbridge-report does not define "unity of nature"—it just mentions a few times the "unified cause-and-effect understanding of the physical world" (f.i. ibid., x)—the unity seems to provide a reason *why* the condition of the possibility of a unification of science is given and, in addition, *why* an advancement of technoscience is feasible. In addition, it is worthwhile to note here that the NSF mainly refers to technologies and, in particular, the cognitive sciences are framed from the perspective of "new technologies". The report prefers to speak about "technologies" and puts less emphasis on terms such as "research" or "sciences". The aim is technology; research is the means.

The NSF-Roco-Bainbridge-report highlights interdisciplinarity as a "synergistic combination".

> "The phrase 'convergent technologies' refers to the synergistic combination of four major 'NBIC' (*nano-bio-info-cogno*) provinces of science and technology, each of which is currently progressing at a rapid rate." (ibid., ix)

The term "synergetic" is one of the most popular terms in contemporary knowledge politics. It was coined by the German physicist Hermann Haken in the late 1960s and, since that time, the term has become tremendously popular. According to Haken, the main principle of synergetics is the "enslavement principle". Due to small differences in initiate conditions caused by natural fluctuations, one mode will become the "master" and "enslaves all other modes"—as shown by Haken in a LASER. As a consequence, just a few order parameters are sufficient to describe a complex system. However, "convergent technologies" in the NBIC-report can mean that one technology enslaves the others. This is, indeed, the case. I will proceed one step further, beyond the symmetry of "NBIC (*nano-bio-info-cogno*)", and concentrate on nanotechnology.[3] Nanotechnology seems to be, more or less, *the* fundamental basis for the unification of technologies because the abstract nanoscale and the nanoobjects are where the convergence of the four technologies is supposed to take place:

> "Convergence of diverse technologies is *based on material unity at nanoscale* and on technological integration from that scale. The building blocks of matter that are fundamental to all sciences originate at nanoscale." (ibid., ix)

Nanoobjects are at the center of the synergistic unification. Everything seems to converge into the very small and abstract world of the nanocosmos. Convergence is the pacemaker to unity; unity is the final point. The final point is the point of total control, the point of Ar chimedes. So it is mainly a unity on the level of objects—in other words: it is an "ontological" unity with regard to nanoobjects. Convergence means convergence of technosciences in technology.

The unity and convergence metaphors are linked with catchwords such as "holism", as stated by the NSF:

> "Converging of the sciences can initiate a new renaissance, embodying a holistic view of technology based on transformative tools, the mathematics of complex systems, and unified cause-and-effect understanding of the physical world from the nanoscale to the planetary scale." (ibid., x).

The traditional metaphysical view of a continuous causality and a causal nexus of nature is re-newed by the NSF in order to highlight the technoscientifc possibility and the importance of unification. In addition, the NSF-claim is that it is "possible to develop a predictive science of society." (ibid., 22) Interdisciplinarity in this broad sense encompasses natural and engineering sciences rather than all disciplines.

> "A trend towards unifying knowledge by combining natural sciences, social sciences, and humanities using cause-and-effect explanation has already begun." (ibid., 13)

To illustrate this trend, a strange (short) poem is placed in the NSF report:

> "If the Cognitive Scientists can think it
> the Nano people can build it
> the Bio people can implement it, and
> the IT people can monitor and control it" (ibid., 13)

Ironically, the IT people would control what the cognitive scientists think. So the naturalistic causal nexus seems to "operate" without the influence of any human agent, like the Laplacian Demon of the early 19th century.

It is taken for granted that the NBIC-technologies—if they are fully developed—will change the world dramatically and move it in a positive direction.

> "Converging technologies could achieve a tremendous improvement in human abilities, societal outcomes, the nation's productivity, and the quality of life." (ibid., ix)

A "new renaissance" and a "next industrial revolution" will emerge and in fact this optimism is at the core of the knowledge politics of the NBIC-advocates. The renaissance was, indeed, a phase of transition—from the medieval age to modern times; since this period, scientific-based technological progress has been equated with human and societal progress. The NBIC-scenario is close to this view developed in the early 17th century. Thus, the vision of the NBIC-advocates is neither unique nor new; rather, it can be traced back to the politician and philosopher Francis Bacon and his contemporaries. During Bacon's time, science and technology were not perceived ambivalently, partly because the negative side effects were not yet known. It was an optimistic age: science-based technologies were regarded as *the* pathway towards future.

However, the NBIC-advocates share a common paradigm: In terms of traditional epistemology, this paradigm is a classical reductionist strategy, although it seems to be a somewhat *neutral* reductionism because, indeed, no reduction toward a unified physics is intended. The NSF criticizes all positions which do not support an overall object oriented interdisciplinary reductionism (or reductionist interdisciplinarity):

> "Some partisans for independence of biology, psychology, and the social sciences have argued against 'reductionism', asserting that their fields had discovered autonomous truths that should not be reduced to the laws of other sciences. But such a discipline-centric outlook is self-defeating, because as this report makes clear, through recognizing their connections with each other, all the sciences can progress more effectively." (ibid., 13)

Hence, fundamental converging technologies are conveyed by an *interdisciplinary technological reductionism* with regard to the nanoobjects based on the metaphysical unity paradigm of (the given and constructed) reality. Reduction here means the reduction to objects (ontological level), not to theories (epistemological level) or methods (methodological level). Apparently, shaping the "bottom", or the nanocosmos, implies an intentional shaping of the meso-, macro- and megacosmos—and a linear determinism for the nanocosmos to the others. Hence interdisciplinary technological reductionists debase other scales of acting in the world, such as the meso-, macro- or megacosmos. These scales are *not* seen as relevant for a general control of the world.[4]

In addition, the NSF-Roco-Bainbridge-report stresses that their understanding of interdisciplinarity shoukd not to be regarded solely as an *organizing principle* but rather as an *integration principle*. To achieve “convergence”, integration is necessary.

> “Convergence means more than simply coordination of projects and groups talking to one another along the way. It is imperative to integrate what is happening.” (ibid., 32)

This passage highlights the fact that in order to understand the type of interdisciplinarity intended by the NBIC-report, an approach by the social sciences regarding project organization, social structures, individual behaviors, personal benefits, and publications and citations is insufficient. An internal knowledge of the state of the art of natural and engineering sciences is indispensable as well as a philosophical reflection on the meaning of “interdisciplinarity”, “integration”, “unity” and “reduction”.

However, of course there are other and very different approaches to nanotechnology and to convergence technologies in the US.[5] But the NBIC-initiative was a and is still one of the most influential kind of *knowledge politics* in the US. Now, we can summarize the assumptions of the NBIC-advocates as follows: 1. *Metaphysical* assumption about the unity of Nature / technonature. 2. *Onto- (techno-) logical* assumption about the unique relevance of nanoobjects in technonature combined with an onto- (techno-) logical reductionism. 3. *Epistemological* assumption about cause-and-effect-reductions of everything—one that also encompasses the social sciences and humanities—combined with a disciplinary scientific non-reductionism. 4. *Methodological* assumption about the outstanding importance of physical methods interlaced with a stress on other intervening, implementing, controlling and transforming methods. 5. Assumption about *purposes, problems and progress* in *s*cience-*t*echnology-*s*ociety (“Baconianism”): human and societal progress is identified with and reduced to technological progress; the purposes, such as “human enhancement”, are given and they need not be discussed further (STS-reductionism).

In the following we further clarify what kind of interdisciplinarity is involved in the NBIC-scenario. To achieve this we present different meaning of “interdisciplinarity” (sect. 3) and look which type fits (sect. 4). It will be shown that the ontotechnological assumptions are the most prominent.

3. An Analytic Framework for Understanding “Interdisciplinarity”

Let us elaborate on what could be meant by “interdisciplinarity” with regard to the NBIC-scenario. To do so it is worthwhile to note that, today, nearly all of those who speak about “interdisciplinarity” in scientific, personal, or public debates pursue certain goals: she or he does not aim only to *describe* science; rather, she or he intends to change, to renew and to re-structure science, and to shape science-based technologies and societies. Normative aspects are always involved; interdisciplinarity in this sense does not leave disciplinarity unaffected and society untouched, although it is not often explicated.[6] An implicit *societal theory*—how can contemporary society be understood and how should the societal future be (shaped)—is always present when “interdisciplinarity” appears. Interdisciplinarity is an eminently *political term*: a core element of the current *knowledge politics*. However, a critical reflection on the way in which NBIC-advocates use the term “interdisciplinarity” should start with some analytical classification.

Such an analysis is missing in the debate on “interdisciplinarity”. In addition to what has been achieved in the field of reflection on interdisciplinarity (e.g., by Chubin/Porter/Rossini/Connolly 1986; Mittelstraß 1987; Thompson Klein 1990; Weingart/Stehr 2000;

Decker 2001; Schmidt 2002; Schmidt 2003; and others), we propose a classification framework of different *types of interdisciplinarity*. A plurality of meanings will be shown which does not have a unifying semantic core. There is not *one* (type of) "interdisciplinarity" but various.[7] Our approach is systematic and analytical and will use of what the philosophy of science has achieved. The well-established differentiation between objects/reality ("ontology"), knowledge/theory ("epistemology"), methods/practices ("methodology"), and further, problem-perception/problem-setting provides a helpful framework for understanding the multi-faceted term "interdisciplinarity".

However, it should be admitted that this paper does not unilaterally follow the unity-advocates, *not* without explicating what unity could mean. For instance, Julie Thompson Klein argues that

> "the modern concept of interdisciplinarity has been shaped in [...] major ways, [in particular] by attempts to retain and, in many cases, reinstall historical ideas of unity." (Klein 1990, 22)[8]
> "The roots of the concepts lie in a number of ideas that resonate throughout the discourse—the ideas of a unified science, general knowledge, synthesis, and the integration of knowledge." (ibid., 19)

In addition, throughout this paper unity is regarded just as *one* element. Other, obviously contrary elements include, for instance, different kinds of non-reductionism and pluralism. Some interdisciplinarians argue for unity, others for non-reductionism. Thus, interdisciplinarity should be regarded as a relational term that carries an unresolvable tension between unity, plurality and disunity, between reducibility and irreducibility, and between reductionism, holism and antireductionism. Interdisciplinarity would be meaningless if it just aimed to reinstall unity and to enable more successful reductions; if this were the case, physics would be most successful way to practice interdisciplinarity.[9]– Now, here is my proposal for a framework of interdisciplinarity:

First object-interdisciplinarity refers to objects and entities (*"ontological" type)*. The historically established functional differentiation into disciplines does not seem to be totally contingent. It rather mirrors aspects of the structure of "reality" itself. Edmund Husserl, Nicolai Hartmann, Alfred North Whitehead and others have argued for a structural-layered concept of reality. Boundaries between the micro-, meso- and macrocosm seem to be evident. Interdisciplinary objects are thought to be located or constructed within the structure of reality. That is, they lie *on* the boundaries between different (micro-, meso-, macro- and other) cosmos or *within* border zones between disciplines, for example the brain-mind object.[10] In order to argue for this position one has to presuppose at least a minimal ontological realism concerning *real* objects, interlaced with a layered concept of reality, and, based on this, an ontological pluralism/non-reductionism.[11] According to this view, the brain-mind object can neither be reduced to the material brain nor to the mental mind but, perhaps, to something neutral which is, in turn, why object-interdisciplinarity can be regarded as a neutral ontology or a neutral monism. Old and ongoing philosophical issues about monism, dualism, and pluralism emerge in this debate. Here, interdisciplinarity does not mainly refer to knowledge, methods, or problems, but to an external, human independent reality.

The foregoing is, of course, a very strong and speculative concept of interdisciplinarity which might be called *universal-object interdisciplinarity*. Some weaker concepts of this position—which will becalled *partial* or *realconstructivistic object interdisciplinarity*—do not claim a timeless existence for interdisciplinary objects on an invariant global scale. According to this view, boundaries and interdisciplinary objects are created by the extended use of technologies[12] or cognitively constructed by sciences themselves,[13] for instance the hole in the ozone layer.[14] The ontological position can be called *real-constructivism*; however, unfortunately this position is not fully developed in the philosophy of science.[15] We show, later in this paper, that nanobots and nanofabrics are excellent examples for a realconstructivistic ontological interdisciplinarity that is rooted not in a classical realism rather in a *Baconian* real-constructivism (Bacon 1950; Bacon 1959).

Second theory-interdisciplinarity: The *epistemological type* of interdisciplinarity focuses on knowledge, theories, and concepts – and not primarily on objects and reality, or on methods and practices. Here, we ask whether interdisciplinary theories do exist and how they may be specified and identified. Can we demarcate interdisciplinary knowledge from disciplinary knowledge and from non-scientific knowledge? Is there a unique context of justification of interdisciplinary theories? Do interdisciplinary models, laws, explications, descriptions, and explanations exist? Possible candidates for theories are meta-theories which can be applied to describe very different disciplinary objects. According to this view, an interdisciplinary theory highlights structural similarities between some properties of objects from various disciplines. Such a theory is not reducible to a disciplinary one—that is, interdisciplinary theories do not fit in the disciplinary framework. An epistemological non-reductionism, with regard to disciplinary theories is the most compelling position.

"Structural sciences" such as complex systems theory are prominent examples. Here, the goal is a cognitive integration and theoretical synthesis of knowledge. Very similar to complex systems theory are theories such as: self organization theory, dissipative structures, synergetics, chaos theory, nonlinear dynamics, fractal geometry, catastrophe theory, etc. Most of these theories were established in the late 1960s and early 1970s, although some foundational work dates back to the late 19th century (Mainzer 1996; Schmidt 2001). Hermann Haken (1980), the founder of *synergetics* in the 1960s, regards synergetics as an "interdisciplinary theory of general interactions".[16] In fact, this type of interdisciplinarity—which might be characterized by metadisciplinary theories or, at least, by non-disciplinary abstract knowledge—is not new. Explicitly, it can be found in work from the 1950s. The physicist and philosopher Carl Friedrich von Weizsäcker coined the term "structural sciences" (Weizsäcker 1974, 22); Weizsäcker writes, structural sciences "study their objects regardless of disciplinary origin and in abstraction from disciplinary allocation". Today, complex systems theory describes process phenomena—such as pattern formation, self organization, critical behavior, bifurcations, phase transitions, structure breaking, and catastrophes[17]—in different disciplinary branches.

Third method-interdisciplinarity: In addition, a *methodological type* of interdisciplinarity can be identified. In general, methodology refers more to knowledge production, the research process, the rule-based action of scientists, and to the languages in use. The central issue of methodology is *how*, and by the application of *which rules*, can we obtain knowledge? (cp. Mittelstraß 2005; Pohl/Hirsch Hadorn 2006) Regarding interdisciplinarity, some central questions are: do interdisciplinary methods and actions exist? Is there a specific context of discovery within interdisciplinary projects? However, interdisciplinary methodologies are thought not to be reducible to a disciplinary methodology.[18]

Bionics (or biomimicry) might be regarded as an example of an interdisciplinary method (Benyus 2002; Nachtigall 1994). The core of the bionic's and biomimicry's methodology is the exchange between two disciplines: biology and engineering sciences. Bionics claims to be a *transfer methodology* from biology to engineering sciences, and probably, what is mostly not admitted, *vice versa*. The central, popular and, of course, questionable idea of bionics can be summarized as follows: "learning from Nature" in order to "inspire technological innovations" and to optimize artifacts and processes (Benyus 2002). Nature seems to provide tricky ideas, inventions and innovations that can be used to construct technology.[19] However, interdisciplinary translations are based on models. Therefore, "learning from Nature" means learning from *models* of Nature. What is called "Nature" is not a given but is constructed, as Immanuel Kant argued: We have to be aware that Nature is perceived and cognitively constructed from the perspective of technology; bionics con structs models of the biological nature based on the perspective of engineering sciences. Thus, the transfer method is not a one-way street; a robot, for example, mimics an ant, but at the same time the ant was investigated and described from a technological perspective.[20] – Besides bionics, there are other examples of interdisciplinary methodologies. Very similar to bionics is econophysics which organizes methodologically a transfer between physics and finance/economics (Mantegna/Stanley 2000; McCauley 2004).

Fourth problem-oriented interdisciplinarity: We should add another level that focuses more on the starting points, the goals, problems and purposes of interdisciplinary research activities—in other words, the *problem framing*, *problem setting* and *problem perception type*. Erich Jantsch argues for a "purposive understanding of interdisciplinarity": an explicit reflection and revision of purposes should be regarded as the highest level of interdisciplinarity. Jürgen Habermas (1970) draws attention to the interests of the sciences and to the purposes of research processes. The problem seeing and setting, and the volition or intention to obtain a certain knowledge precedes both the context of discovery and the context of justification, i.e. the methods and theories. There is an immanent teleological structure in the process of knowledge production.

However, the very first step in scientific inquiry is mostly judged to be an external contingent factor and, thus, it has been widely ignored by philosophy of science, although extended work has been done on problems called "wicked problems" (Rittel/Webber 1973; Norton 2005, 131f/159f).[21] This lack of reflection turns out to be a deficit for specifying this kind of "interdisciplinarity". And, with regard to the history of interdisciplinarity and Erich Jantsch's classical approach in the 1970s, reference to problems and purposes was a unique qualification for demarcating interdisciplinarity from disciplinarity. Interdisciplinary problems are somewhat external to *disciplines* or to *sciences*: these problems are primarily societal ones which are mainly due to *and* defined by society, lay people, politicians, and stakeholders.[22] These problems demand a solution for the societal prospect. Interdisciplinarity has a functional side *for* (in order to organize!) the future progress of scientific-technological civilization. Excellent examples are sustainability research or technology assessment (Decker 2001). They all refer to, reflect and revise goals and purposes of our development. In particular Erich Jantsch has highlighted the "purposive level" of interdisciplinarity (Jantsch 1972, 103).[23] Problem-oriented interdisciplinarity in this sense is seen as an instrument to overcome disciplinary limitations from a purposive and goal-setting perspective in order to secure societal progress.

Not everyone will agree to *all* of the above mentioned types of "interdisciplinarity". Philosophical stances and underlying convictions will determine which of the four types one might consider as the most important and what other types will just be viewed as inferences or mere consequences.[24]

4. Specifying the Type of Interdisciplinarity in the NBIC-Scenario

However, based on the framework of the four types of interdisciplinarity, we can address the question about which type is the most present in the NBIC-scenario. It is worthwhile to note that the NBIC-advocates do not have much to offer with regard to theories and methods, and they offer only minor elements with regard to problems and purposes (cp. Schummer 2004).

Theory: A coherent theory is not the aim of the NBIC-advocates. A patchwork of models would work well for them, if it provides an efficient basis for action, intervention and prediction. Theories are not regarded as ends-in-themselves; rather, they are means and instruments. Briefly put, technology is the aim, not theory; technological intervention in stead of theoretical representing. On the other hand, the NBIC-advocates realize that theoretical elements are indispensable. In order to develop enabling technologies we have to "integrate what is happening." (Roco/Bainbridge 2002, 32) For enabling technologies nothing is more practical than an adequate theory. This makes the NBIC-scenario a perfect example of a technoscience that merges natural sciences, engineering sciences, and technology. However, the NBIC-advocates do not have a strong understanding of a "theory", e.g., their understanding of a theory is not in the sense of a deductive-nomological explanation which is still the aim of the unification project of physics. Thus, it is convincing that the NBIC-advocates are reluctant and prefer to speak about the integration of knowledge rather than about a theory of everything. – Although the aim of the NBIC-advocates requires *some* theories, it is hard to see any common theoretical umbrella or any interdisciplinary theory in the NBIC-scenario—even if we refer to a weak understanding of theory. Surely, we find progress in regard to theories within the branch of disciplinary (nano-) physics but rarely in the frame of a theory that could be called "interdisciplinary" (cp. Schummer 2004).[25]

Method: Similar to the lack of a theoretical framework, a common method and a unified methodology are not the aim of the NBIC-advocates. Methods are regarded as means to obtain knowledge. What matters most is the efficiency and the effectiveness of methods, not any process of unification. If unification can help to increase efficiency, it is highly desired; however, the methods we find in the NBIC-branch are based on advancements in the realm of physics. The first programmatic speech on nanotechnology was given by the physicist Richard Feynman in 1959 in which he declared that there seems to be "plenty of room at the bottom". And the NBIC-technologies are mainly driven by methodological improvements in the area of physics. For the rise of nanotechnology, physical instruments such as the *scanning tunneling microscopy* (STM) and the *atomic force microscope* (AFM) are of major importance. They stem from advanced developments of physics in the early 1980's. If the core of the NBIC-scenario is rooted in nanotechnology, then it is also rooted in physics. Thus, in fact there is more method-disciplinarity than -interdisciplinarity.

Problem: In addition, the NBIC-convergence can hardly be regarded as problem-oriented—it is rather technoobject-oriented. General goals are formulated such as human enhancement, basic needs/food of the LDC, and a "new renaissance". However, problem-orientation, as the term is used throughout this paper, means to focus on, to frame and to solve societal problems by explicitly reflecting on goals—and partly by making use of and developing new technologies. The NBIC-advocates do not explicate or attempt to initiate a discourse about purposes. However, their purpose seems to be the fascinating technological development in itself interlaced with the unspecific idea of human enhancement. For instance, the NBIC-advocates do not have broad reservations with regard to military uses. An improvement of converging technologies for battlefield domination does not seems to be undesirable. Thus, the NBIC-scenario does not fit into the reflexive concept of *problem-oriented interdisciplinarity* (see also the last section of this paper). In order to compensate the deficit, concepts of technology assessment (as vision assessment) and shaping of technology have been developed (Grundwald/Grin 2000; Fleischer 2002; Fleischer 2003; cp. also: Grunwald 2005; Schmid et al. 2006).

Object: Therefore, if our main findings are negative—if there is a lack of theory- and method-interdisciplinarity within the NBIC-scenario, and very limited, if any at all, problem-oriented interdisciplinarity—what can be said about *object-interdisciplinarity*? According to our definition, we have to take two different kinds of object-interdisciplinary into account. (a) The *strong version* assumes that the some objects are timelessly located on boundaries due to the universal layers of reality (*universal object-interdisciplinarity*). Ac cording to this ontological realism, these objects can be called interdisciplinary objects. (b) A *weaker version* states that the boundaries have not and do not exist forever (*partial* or *realconstructivistic object-interdisciplinarity*). Boundaries are constructed by the way humans construct reality. We construct boundaries and construct objects on boundaries—in short: boundary-objects.

In fact, the "objects" of the NBIC-scenarios are the constructed technologies. They have not existed before and do not exist independently in Nature, independently of humans, although they are based on the laws of Nature: e.g., new materials, new products and processes. According to the NBIC-advocates, nanoobjects seem to be, more or less, *the* fundamental basis for the convergence of technologies. It is a convergence in objects, not in theories or methods. The nanoobject is scale where the convergence of the four technologies is supposed to take place:

> "Convergence of diverse technologies is based on material unity at nanoscale and on technological integration from that scale. The building blocks of matter that are fundamental to all sciences." (Roco/Bainbridge 2002, ix)

In the very small and realconstructed world of the nanocosmos, everything seems to converge. Here, the nanotechnoscientific objects might be labeled "interdisciplinary". It is interesting to see how the realconstructed nanoobjects relate to physics. *On the one hand*, nanoobjects belong to the domain of physics; they are located on boundaries between the quanten-microcosmos and the mesocosmos. *On the other hand* the NBIC-advocates aim to produce *instrumental knowledge* about/for enabling technologies and not to obtain *true knowledge* of basic research, such as in the old-fashioned physics. Although the boundaries between physics and engineering sciences are highly disputed, it is worthwhile to stress that "convergence technology" does not mean a convergence to objects that just belong to the disciplinary physics but rather a converegence to technoscientific nano-objects—that are objects for technological purposes. This is the reason why in the NBIC-scenario we do not have a reduction to disciplinary objects such as objects of physics but a reduction to interdisciplinary (realconstructed) objects. In this sense nanoojects are located between physics, chemistry, biology, and some engineering sciences.[26] Here, Richard Feynman, the early protagonist of nanotechnology, identified that "There is plenty of room at the bottom" for non-disciplinary nanoobjects.[27]

In consequence, a *realconstructivistic object-interdisciplinarity* turns out to be the base of the NBIC-scenario—this is not a strong type of interdisciplinarity (cp. Schummer 2004).[28] These techno-objects seem to be at the core of the heterogeneous and diverse fields of the umbrella term "nanotechnology", including electron-beam and ion-beam fabrication, molecular-beam epitaxy, nanoimprint lithography, projection electron microscopy, atom-by-atom manipulation, quantum-effect electronics, semiconductor technology, spintronics and microelectromechanical systems. Here, interdisciplinary objects are essential parts of the recent reality or the reality to come ("ontological level").[29]

5. Realconstructivistic Object-Interdisciplinarity: Renewing the Baconian Project

The rhetoric of knowledge politics has always been around; however, today it is put into practice to its full extent. The realconstructivistic object-interdisciplinarity is not an invention of the NBIC-advocates. It can be traced back to Francis Bacon and his concept of science in the early 17th century. The politician and philosopher Bacon was generally not interested in theories but in changing the world and constructing objects.

Bacon proclaimed that science is an instrument to extend the power of man as far as possible (see: Bacon 1959; Bacon 1990). Knowledge is power—Bacon might be a key figure in the history of *knowledge politics*! Nature should be hunted by sciences like an animal in order to unveil her secrets; nature was for man to milk. The main objective is to "master the things" (Novum Organon I, Aph. 29). Bacon did not wish

> "a history of nature at liberty and in her usual course, when she […] acts of her own accord, […] but much rather a history of nature constrained and perplexed, as she is seen when thrust down from her proper rank and harassed and modeled by the art and contrivance of man." (Novum Organon I, Foreword)

Indeed, this view of nature became dominant in the concept of modern science and it was put into practice within its experimental and technological framework. In contrast to the Aristotelian understanding of nature, nothing is given and everything can be technologically manipulated. *Homo Sapiens* became *Homo Faber*, and they further aspires to become today's *technoscience S@piens*. Science-based technological development became identified with social and human progress (cp. Böhme 1993). This identification was doubted from the 1960's until the middle of the 1990's, but evidently just for this short epoch. In the late 1990's technological optimism returned again to science, technology and politics: the Baconian Project seems to be the leading underlying ethos of scientists and engineers working in fields of NBIC-convergence.

The visions of a science-based technological shaping and manipulation of the world are not new. They are rooted in the history of our culture. In the empiricist tradition David Hume confirms the Baconian Project:

> "The only immediate utility of all science is to teach us how to control and regulate further events [in nature]." (Hume 1990, 76)[30]

Thus, the NSF-phrase "shaping the world atom by atom" (cp. Nordmann 2003) is not new in general, but rather it is an extension and a new summit of the Baconian Project that has been in development since the 17th century.[31] Although technology became science-based in general in the 19th century, the 21st century will probably be the century of the emergence of fundamental engineering sciences and an overall technoscientific reductionism. In line with a general technological optimism the physicist Michio Kaku states today:

> "For most of human history, we could only watch, like bystanders, the beautiful dance of Nature. But today, we are on the cusp of an epoch-making transition, from being passive observers of Nature to being active choreographers of Nature. The Age of Discovery in science is coming to a close, opening up an Age of Mastery." (Kaku 1998, 17)

Nanotechnology is the tip of the Baconian iceberg. But, until today, Bacon's Project and his vision has not been realized and put into practice to its full extent. Bacon speaks in favor of a science-based reductionist "technological foundation", a fundament for acting and manipulating the world. The NSF's phrases resemble Bacon's words:

> "If we make the correct decisions and investments today, many of these visions could be addressed within 20 years' time. Moving forward simultaneously along many of these paths could achieve an age of innovation and prosperity that would be a turning point in the evolution of human society" (Roco/Bainbridge 2002, x)

The emergence of the new NBIC-based innovations has renewed the convictions of "Nova Atlantis" to support not only scientific explorations and "truth" production but (also) mainly discoveries, inventions, and innovations (see: Bacon 1959; Bacon 1990). Everything seems to be shaped, designed and controlled within the limits of the laws of nature. However, Bacon dreamed of knowledge politics whereas today this policy field is put into practice.[32]

6. Prospects: NBIC-Scenario *versus* CTEKS-Initiative of the European-Commission

There is always a choice: the kind of interdisciplinarity can be chosen deliberately. In order to deepen the analysis of recent *NBIC-knowledge politics* let us contrast the US-NBIC-scenario with another prominent initiative.[33] In 2004 an expert group of the European Commission met the challenge of the NBIC-initiative and developed "a specifically Euro pean approach to converging technologies" (Nordmann et al. 2004). The group released in 2004 a report entitled "Converging Technologies – Shaping the Future of European Societies." This concept is called "CTEKS—*C*onverging *T*echnologies for the *E*uropean *K*nowledge *S*ociety". Obviously, the Europeans do not focus mainly on human enhancement but on broader aspects of societal innovation. Their aim is, as we will see, to "widen the circles of convergence".

Similar to the NBIC-scenario, interdisciplinarity is also highly esteemed by the CTEKS-advocates. However, the CTEKS-interdisciplinarity seems to be much broader than the NBIC's; the concept of CTEKS is *problem-orientated* rather than *object-oriented*. The CTEKS-advocates aim to take many aspects into account, so they speak about "Nano-Bio-Cogno-Socio-Anthro-Philo-Geo-Eco-Urbo-Orbo-Macro-Micro". Most important is that CTEKS intends not just a convergence of technologies or of technosciences but rather:

> "Converging technologies converge towards a common goal [or shared visions].[34] CTs always involve an element of agenda-setting. Because of this, converging technologies are particularly open to the deliberate inclusion of public and policy concerns. Deliberate agenda-setting for CTs can therefore be used to advance strategic objectives such as the Lisbon Agenda." (Nordmann et al. 2004, 4)

The societal goals, purposes and aims are the focus, in particular the *setting* of the goals. According to the CTEKS-advocates the goals for the future of the European technoscientific civilization should be *participatory governance*. Not only experts but also lay people should participate in this process.

> "C*TEKS* agenda-setting is not top-down but integrated into the creative technology development process. Beginning with scientific interest and technological expertise it works from the inside out in close collaboration with the social and human sciences and multiple stakeholders through the proposed WiCC-initiative („Widening the Circles of Convergence"). For the same reason, ethical and social considerations are not external and purely reactive but through the proposed EuroSpecs process bring awareness to CT research and development." (ibid., 4)

The foregoing is a perfect explication of the problem-oriented interdisciplinarity, strictly in contrast to all kinds of object-interdisciplinarity: "Widening the Circles [!] of Convergence" means to reject the metaphysical "unity-of-nature" metaphor of US-NBIC-initiative, its cause-and-effect-terminology and its reductive (techno-) object orientation, and to take broader aspects of the "Socio-Anthro-Philo-Geo-Eco ..." into account. Circle*s* is explicitly formulated pluralistically: many different kinds of convergence are feasible. By widening the circles the CTEKS-initiative wants to overcome what Segerstrale has severely criticized: "The missing discourse about science and society" (Segerstrale 2000). Ethical considerations in public discourses should serve as guidelines to explicitly (co-) shape the trajectories towards the future and to enable path decisions for reaching the goals. These trajectories should be set and selected in order for them to converge with societal goals, cultural needs, and ethical considerations. By these terms, some of the trajectories of the NBIC-advocates are criticized and rejected:

> „Converging Technologies (CTs) present equally significant opportunities and challenges." (ibid., 4) "Agendas for convergence include „Converging technologies for improving human performance" or „Converging technologies for battlefield domination." The expert group does not recommend there or any one such agenda. By proposing „Converging technologies for the European Knowledge Society (C*TEKS*)," it places the emphasis on the agenda-setting process itself. It envisions that various European CT research programs will be formulated, each addressing a different problem and each bringing together different technologies and technology-enabling sciences. These might include „CTs for natural language processing," „CTs for the treatment of obesity," or „CTs for intelligent dwelling." (ibid., 4)

Indeed, this is a broad understanding of convergence linked with a broad understanding of interdisciplinarity. However, the European expert group offers 16 recommendations, among them "interdisciplinarity" which is more than an organizational principle:

> "Interdisciplinarity should be strengthened, beyond planned or institutional collaboration, in program calls and research policies from the Commission and from the European nations."

> (ibid., 4) Further: "CT modules should be introduced at secondary and higher education levels to synergize disciplinary perspectives and to foster interaction between liberal arts and the sciences." (ibid., 5) "Commission and Member States need to recognize and support the contributions of the social sciences and humanities in relation to CTs, with commitments especially to evolutionary anthropology, the economics of technological research and development, foresight methodologies and philosophy." (ibid., 5)[35]

So the European CTEKS-advocates are not arguing for a naturalization of social sciences and humanities; in particular they are very reluctant to speak about a unity of nature, integration, a unity of science and cause-and-effect-explanations.

This comparison of the two contrasting visions of *Converging Technologies* might provide a further argument that the classification of different types of interdisciplinarity is a helpful analytic tool to investigate research programs and recent knowledge politics. Realconstructivistic Object-interdisciplinarity and problem-oriented-interdisciplinarity are very different. This distinction might serve as a cornerstone for critically assessing the fluid buzzword "interdisciplinarity" in the various contexts of recent knowledge politics—which raises the question: Should the object or the problem-oriented type of interdisciplinarity guide the knowledge politics for our common future?[36]

References

Ahluwalia, P., 1994: Big science in Canada. Ressource book for science and technology consultations; Ottawa

Bacon, F., 1959/1627: Neu-Atlantis (hg. v. Gerber, G.), Akademie Verlag: Berlin

Bacon, F., 1950: Neues Organon: Teilband 1 (hg. v. Krohn, W.), Felix Meiner: Hamburg

Baird, D., Nordmann, A., Schummer, J. (eds.): 2004, Discovering the Nanoscale, Amsterdam

Bechmann, G., Frederichs, G., 1996: Problemorientierte Forschung. Zwischen Politik und Wissenschaft. In: Bechmann, G. (eds.), 1996: Praxisfelder der Technikfolgenforschung; Frankfurt, p. 11-37

Bechmann, G., Petermann, Th. (eds.), 1994: Interdisziplinäre Technikforschung. Genese, Folgen, Diskurs; Frankfurt

Benyus, J.M., 2002: Biomimicry: Innovation Inspired by Nature; New York: HarperCollins

BMBF (Bundesministerium für Bildung und Forschung), 2004: Nanotechnologie erobert Märkte: Deutsche Zukunftsoffensive für Nanotechnologie (http://www.bmbf.de/pub/nanotechnologie_erobert_maerkte.pdf.)

Böhme, G., van den Daele, W., Krohn, W., 1974: Die Finalisierung der Wissenschaft; In: Diederich, W. (ed.), 1974: Theorien der Wissenschaftsgeschichte; Suhrkamp, Frankfurt, 276ff

Böhme, G., Stehr, N., 1986: The Knowledge Society; Dordrecht

Böhme, G., 1993: Am Ende des Baconschen Zeitalters; Suhrkamp, Frankfurt

Boeing, N., 2004: Nano?! Die Technik des 21. Jahrhunderts; Berlin.

Carrier, M., 2001: Business as Usual: On the Prospect of Normality in Scientific Research; In: Decker, M. (ed.), 2001: Interdisciplinarity in Technology Assessment; Berlin, p. 25-31

Chubin, S., Porter, A.L., Rossini, F.A., Connolly, T. (eds.), 1986: Interdisciplinary Analysis and Research. Theory and Practice of Problem-Focused Research and Development; Mt Airy, MD: Lomond

Coenen, Chr., Rader, M., Fleischer, T., 2004: Of visions, dreams and nightmares: The debate on converging technologies; Technikfolgenabschätzung - Theorie und Praxis, 13(3), p. 118-125.

Cozzens, S.E., Gieryn, T.F. (eds.), 1990: Theories of Science in Society; University Press, Indiana

Crandall, B.C. (ed.), 2000: Nanotechnology. Molecular Speculations on Global Abundance; MIT Press, Cambridge/Mass.

De Bie, P., 1970: Problemorientierte Forschung. Bericht an die Unesco; Frankfurt

Decker, M. (ed.), 2001: Interdisciplinarity in Technology Assessment. Implementation and its Chances and Limits; Springer, Berlin

Drexler, K.E., 1990: Engines of Creation: The Coming Era of Nanotechnology; Fourth Estate

Etzkowitz, H., Leydesdorff, L. (eds.), 1997: Special Issue on Science Policy Dimensions of the Triple Helix of University-Industry-Government Relations, Science & Public Policy 24(1), p. 2-52.

Euler, P., 1999: Technologie und Urteilskraft; Weinheim: Beltz

Feynman, R.E., 1959/2003: There's Plenty of Room at the Bottom; In: http://www.zyvex.com/nanotech/Feynman.html .

Fleischer, T., 2002: Technikfolgenabschätzungen zur Nanotechnologie. Inhaltliche und konzeptionelle Überlegungen; In: Technikfolgenabschätzung, 11(3 / 4), p. 111-122.

Fleischer, T., 2003: Technikgestaltung für mehr Nachhaltigkeit: Nanotechnologie. In: Coenen, R., Grunwald, A. (eds.), 2003: Nachhaltigkeitsprobleme in Deutschland. Analyse und Lösungsstrategien; Berlin, p. 356-373.

Funtowicz, S.O., Ravetz, J.R., 1993: Science for the post-normal age; Futures, Sept. 1993, p. 739-755

Galison, P., 1996: Computer Simulations and the Trading Zone, in: Galison, P., Stump, D.J. (eds.), 1996: The Disunity of Science. Boundaries, contexts, and power; Stanford/CA: Stanford University Press, p. 118-157

Gibbons, M. et al., 1994: The New Production of Knowledge; Sage, London

Gieryn, T.F., 1983: Boundary work and the demarcation of science from non-science. Strains and interests of professional ideologies of scientists; In: American Sociological Review 48, p. 781-795
Gieryn, T.F., 1999: Cultural Boundaries of Science: Credibility on the Line; Chicago: University of Chicago Press
Grunwald, A., 2000: Against Over-Estimating the Role of Ethics in Technology; In: Science and Engineering Ethics, 6, p. 181-196.
Grunwald, A., Grin, J. (eds.), 2000: Vision Assessment – Shaping Technology in 21st Century Society: Towards a Repertoire for Technology Assessment; Springer, Berlin
Grunwald, A., 2005: Nanotechnology – A New Field of Ethical Inquiry?; In: Science and Engineering Ethics 11, p. 187-201
Haraway, D., 1995: Die Neuerfindung der Natur; Frankfurt.
Hacking, I., 1996: Einführung in die Philosophie der Naturwissenschaften; Stuttgart: Reclam
Haken, H., 1980: Dynamics of Synergetic Systems; Berlin: Springer
Hentig, H. v., 1972: Magier oder Magister? Über die Einheit der Wissenschaft im Verständigungsprozeß; Stuttgart
Hill, B., 1998: Erfinden mit der Natur. Strukturen und Funktionen biologischer Systeme als Innovationspotentiale für die Technik; achen: Shaker Verlag
Hume, David 1990. Enquiries concerning human understanding, Oxford: University Press
Jantsch, E., 1972: Towards Interdisciplinarity and Transdisciplinarity in Education and Innovation;CERI, Interdisciplinarity, Paris (auch unter dem Titel: Inter- and Transdisziplinarity University: A Systems Approach to Education and Innovation; Policy Sciences 1, 1970, p. 403-428)
Jantsch, E., 1980: The Self-Organizing Universe. Scientific and Human Implication, New York: Pergamon
Jaeger, J., Scheringer, M., 1998: Transdisziplinarität. Problemorientierung ohne Methodenzwang, in: GAIA 7/1:10-25
Kaku, M., 1998: Zukunftsvisionen. Wie Wissenschaft und Technik des 21. Jahrhunderts unser Leben revolutionieren; Munich
Khushf, G., 2004: Systems Theory and the Ethics of Human Enhancement; in: Baird, D., Nordmann, A., Schummer, J. (eds.): 2004, Discovering the Nanoscale, Amsterdam: IOS, p. –34.
Klein, J T., 2001: The Discourse of Transdisciplinarity: An expanding global field; In: Klein, J.T., et al., 2001: Transdisciplinarity: Joint Problem Solving among Science, Technology, and society; Basel, 35-44
Kline, S.J., 1995: Conceptual Foundations of Multidisciplinary Thinking; Stanford, Stanford University Press
Knorr-Cetina, K.D., 1999: Epistemic Cultures; Harvard Uni Press, Cambridge/MA
Kocka, J. (ed.), 1987: Interdisziplinarität. Praxis – Herausforderung – Ideologie; Frankfurt
Kockelmans, J.J. (ed.), 1979: Interdisciplinarity and Higher Education; Penn State Uni Press, University Park and London
Küppers B-O, 2000: Strukturwissenschaften als Bindeglied zwischen den Natur- und Geisteswissenschaften. In: Küppers, B.-O. (ed.), 2000: Die Einheit der Wirklichkeit. Zum Wissenschaftsverständnis der Gegenwart. München, 89–106
Latour, B., Woolgar, S., 1979: Laboratory Life. Princeton, NJ: Princeton University Press.
Latour, B., 1987/1999: Science in Action, Cambridge/Mass.
Löwy, I., 1992: The strength of loose concepts: Boundary concepts, federative experimental strategies and disciplinary growth: The case of immunology, in: History of Science, 30, p. 371-95
Mainzer, K., 1996: Thinking in complexity. The complex dynamics of matter, mind, and mankind. Heidelberg
Mantegna, R.N., Stanley, H.E., 2000: An Introduction to Econophysics: Correlations and Complexity in Finance; Cambridge
McCauley, J.L., 2004 Dynamics of Markets: Econophysics and Finance; Cambridge/UK: Cambridge University Press
Mehta, M.D., 2002: Nanoscience and Nanotechnology: Assessing the Nature of Innovation in these Fields; Bulletin of Science, Technology & Society, 22(4), p. 269-273
Mittelstraß, J., 1987: Die Stunde der Interdisziplinarität? In: Kocka, J. (ed.): Interdisziplinarität. Praxis, Herausforderung, Ideologie. Frankfurt: Suhrkamp, p. 152-158
Mittelstraß, J., 1998: Die Häuser des Wissens; Frankfurt
Mittelstraß, J., 2005: Methodische Transdisziplinarität; In: Technikfolgenabschätzung. Theorie und Praxis, 14(2), pp. 18-23
Nachtigall, W., 1994: Erfinderin Natur. Hamburg
Nordmann, A., 2002: Shaping the World Atom by Atom: Eine nanowissenschaftliche WeltBildanalyse; Oct. 2002, TU Darmstadt, In: Grunwald, A. (ed.), 2003: Technikgestaltung; Springer, Berlin
Nordmann, A., 2004: Was ist TechnoWissenschaft? - Zum Wandel der Wissenschaftskultur am Beispiel von Nanoforschung und Bionik, in: Rossman, T., Tropea, C. (eds.): Bionik: Aktuelle Forschungsergebnisse in Natur-, Ingenieur- und Geisteswissenschaften, Berlin 2004, p. 209-218
Nordmann, A., et al., 2004: High Level Expert Group "Foresighting the New Technology Wave": Converging Technologies – Shaping the Future of European Societies; European Commission, Bruxelles (ftp://ftp.cordis.lu/pub/foresight/docs/ntw_report_nordmann_final_en.pdf)
Norton, B.G., 2005: Sustainability. A Philosophy of Adaptive Ecosystem Management; University of Chicago Press, Chicago/London
Pohl, C., Hirsch Hadorn, G., 2006 Gestaltungsprinzipien für die transdisziplinäre Forschung; München: oekom.
Rittel, H.W., Webber, M.M., 1973: Dilemmas in a General Theory of Planning, n: Policy Sciences, 4, pp. 155-169.
Roco, M.C., Bainbridge, W.S. (eds.), 2002: Converging Technologies for Improving Human Performance. Nanotechnology, Biotechnology, Information Technology and Cognitive Science; National Science Foundation, Arlington/Virginia
Roco, M.C., Williams, S., Alivisatos, P., 1999: Nanotechnology Research Directions: IWGN Workshop Report. Vision for Nanotechnology Research and Development in the Next Decade; NSF/CT, Washington
Ropohl, G., 1979: Eine Systemtheorie der Technik. Zur Grundlegung der allgemeinen Technologie. München
Ropohl, G., 1981: Interdisziplinäre Technikforschung; Berlin

Ropohl, G., 2002: Rationalität und Allgemeine Systemtheorie. Ein Weg synthetischer Rationalität. In: Karafyllis N., Schmidt J.C. (eds.), 2002: Zugänge zur Rationalität der Zukunft. Stuttgart, 113–137

Roukes, M.L., 2001: „Unten gibt's noch viel Platz"; Spektrum der Wissenschaft Spezial, 2001: Nanotechnologie; 2/2001, p. 32-39.

Schmid, G. et al., 2003: Small Dimensions and Material Properties. A Definition of Nanotechnology; Graue Reihe Nr. 35, Bad Neuenahr-Ahrweiler/Germany

Schmid, G. et al., 2006: Nanotechnology. Assessment and Perspectives; Bd. 27, Springer, Berlin

Schmidt, J.C., 2001: Was umfaßt heute Physik? Aspekte einer nachmodernen Physik; In: Philosophia Naturalis 38, p. 271-297.

Schmidt, J.C., 2002: Interdisziplinäre Erkenntniswege. Versuch einer wissenschaftsphilosophischen Charakterisierung; In: Krebs, H. et al. (eds.), 2000: Perspektiven Interdisziplinärer Technikforschung. Konzepte, Analysen, Erfahrungen; Münster, p. 55-72

Schmidt, J.C., 2003: Wundstelle der Wissenschaft. Wege durch den Dschungel der Interdisziplinarität; In: Scheidewege, 33, p. 169-189

Schmidt, J.C., 2004: Unbounded Technologies. Working Through the Technological Reductionism of Nanotechnology", In: Baird, D. et al. (eds.), 2004: Discovering the Nanoscale, Amsterdam, 2004, 35-51.

Schmidt, J.C., 2005: Dimensionen der Interdisziplinarität. Wege zu einer Wissenschaftstheorie der Interdisziplinarität; In: Technikfolgenabschätzung. Theorie und Praxis, 14(2), p. 12-17

Segerstrale, U. (ed.), 2000: Beyond science wars: The missing discourse about science and society; New York: State University of New York Press

Smalley, R.E., 2001: Chemie, Liebe und dicke Finger; In: Spektrum der Wissenschaft Spezial, 2001: Nanotechnologie; 2/2001, p. 66-67.

Snow, C.P., 1967: Die zwei Kulturen. Literarische und naturwissenschaftliche Intelligenz. Stuttgart (The two cultures 1959)

Sokal, A., Bricmont, J., 1999: Eleganter Unsinn. Wie die Denker der Postmoderne die Wissenschaften mißbrauchen. München

Spektrum der Wissenschaft Spezial, 2001: Nanotechnologie; 2/2001

Star, S.L., Griesemer, J.R., 1989: Institutional ecology: ‚Translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology 1907-39, in: Social Studies of Science, 19, p. 387-420

Stehr, N., 1994: Knowledge Societies; London.

Stehr, N., 2001: Knowledge politics: the paradox of regulating knowledge dynamics; In: Maasen, S., Winterhager, M. (eds.), 2001: Science Studies. Probes into the Dynamics of Scientific Knowledge; Bielefeld, Transcript, p. 269-290.

Stehr, N., 2005: Knowledge Politics: Governing the Consequences of Science and Technology; Paradigm Publisher

Stix, G., 2001: Little Big Science; Scientific American, Sept. 2001, 32ff

Thompson Klein, J., 1990: Interdisciplinarity: History, Theory, and Practice; Detroit, Wayne State University

Thompson Klein, J., 1996: Crossing Boundaries: Knowledge, Disciplinarities, and Interdisciplinarities; Charlottesville, University Press of Virgina

Thompson Klein, J., et al. (eds.), 2001: Transdisciplinarity: Joint Problem Solving among Science, Technology, and society; Basel

Weingart, P., Stehr, N. (eds.), 2000: Practising Interdisciplinarity; University of Toronto Press, Toronto

Weizsäcker, C.F. v., 1974: Die Einheit der Natur; München: dtv

Ziman, J., 1996: Postacademic Science: constructing knowledge with networks and norms, in: Science Studies 1, p. 64-79

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[1] See, f.i.: Ropohl (1981), Mittelstraß (1987), Thompson Klein (1990), Bechmann/Frederichs (1996), Jaeger/Scheringer (1998), Euler (1999), Weingart/Stehr (2000), Decker (2001), Schmidt (2003), Schmidt (2005) and others.

[2] Indeed, the NBIC-visionaries are very successful in their advertising strategy to obtain funding money.

[3] It is pretty unclear how to understand and define nanotechnology: see the excellent study of Schmid et al. (2006).

[4] The meso-, macro- or megacosmos do *not* seem to possess own supervenient properties. This is, of course, a strong claim and reveals the straight naturalistic viewpoint which is based on the (classical) conviction of a continuous cause-and-effect nexus of the world, especially a naturalistic line from the nanocosm to the macrocosm. The phrase "shaping the world atom-by-atom" neglects classical engineering sciences on scales of the micro-, meso-, macro- or megacosmos and just focuses on the nanocosm.

[5] It is worthwhile to note that there are also other initiatives with different approaches in the US forstering in particular "nanotechnology". Let me just mention some aspects of the NBIC-knowledge politics. – Generally, in November 2003 the US Senate passed the *21st Century Nanotechnology Research and Development Act*, in order to "authorize appropriations for nanosciences, nanoengineering and nanotechnology research." – In addition, there existis a *Center for Responsible Nanotechnology* (www.crnano.org/) that is a non-profit research and advocacy think tank concerned with "the major societal and environmental implications of advanced nanotechnology." It is a networked organization—a collection of more than 100 volunteers, over 1000 interested followers, and a small team of primary coordinators. – And, the *Nano-ethics Group* (www.nanoethics.org/) that is a non-partisan and independent organization focused generally on the ethical and social implications of nanotechnology. – In particular the project "Creativity capabilities and the promotion of highly innovative research in Europe and the United States (CREA)" at the *Georgia Institute of Technology/Atlanta*: Researchers from the Technology Policy and Assessment Center (TPAC) at Georgia Tech's School of Public Policy are collaborating

with two European partners, the Fraunhofer Institute for Systems and Innovation Research (ISI) and Sussex University's Science and Technology Policy Research Unit (SPRU) in a new study to examine creative capabilities and the promotion of highly innovative research in Europe and the United States (CREA). One of the two major fields of focus of the study is nanotechnology (The second is human genetics). The project is sponsored by the Newly Emerging Science and Technologies (NEST) program of the European Union. – Further: The *Center for Nanotechnology in Society* at *Arizona State University* (CNS-ASU) helps ensure "that advances in nanotechnology bring about improvements in the quality of life for all Americans" (PL 108-153). The Center's vision is that research into the societal aspects of nanoscale science and engineering (NSE), carried out in close collaboration with NSE scientists and combined with public engagement, will improve deliberation and decision making about NSE. CNS-ASU builds the capacity to address the societal implications of NSE by creating a broad institutional network, instituting a coherent research program, promoting innovative educational opportunities, and engaging in meaningful participation and outreach activities, especially with under-represented communities. Its goal is nothing less than charting a path toward new ways of organizing the production of knowledge and developing and testing new processes of anticipatory governance to meet the emerging promise and challenges of NSE. – In addition there are several projects; see the *international nanotechnology and society network* (www.nanoandsociety.com/). – See also the European Nanotechnology Gateway: www.nanoforum.org/

[6] Mittelstraß (1987, 152) stresses: "Interdisciplinarity always changes the disciplinarity pattern, the methods and approaches. There exists an eminent feedback and impact on disciplinarity".

[7] Some philosophical traditions will argue for *one* basic understanding and a particular core content, for instance an approach from the perspective of the *scientific realism*. But I will not presuppose such a position; rather I will look at the various approaches.

[8] In other words: "All interdisciplinary activities are rooted in the ideas of unity and synthesis, evoking a common epistemology of convergence." (Klein 1990, 11)

[9] However, beside unity there were various other elements such as problem-orientation and –resolution that have to be regarded as motivational elements of interdisciplinarity.

[10] Here we see that interdisciplinary objects are related to a position in philosophy that is called „neural onotology".

[11] Ontological reductionism is known as the stance stating that the world consists (totally) of atoms or other fundamental material entities ("materialism") *or*, on the contrary, of mental entities ("idealism").

[12] This position might be called "real-constructivism" or "materialistic constructivism".

[13] This is the classical "cognitive constructivism" or "idealistic constructivism".

[14] They do not exist since the beginning of the world. It might be disputed whether these objects are by themselves "interdisciplinary" or, on the contrary, whether they are just perceived, described, or shaped under an interdisciplinary perspective. Although it might be controversial whether *a particular* object is evidently labeled "interdisciplinary" – for instance, a technical object may be seen as a disciplinary object of engineering sciences or as an interdisciplinary object, and it should not be doubted that these are the *same* objects – interdisciplinary objects seem to exist at least for a certain time. And, the future development of science may shift these objects to domains of new unified disciplines or, similarly, it may be shown that they belong to fields of classical, already-existing disciplines. So the ontological boundaries become time dependent—and also minimal dependent on our abilities, our knowledge, and our technological skills.

[15] This holds although, f.i., the "new experientalism" has broadly argued in favor of it. This position traces back to Francis Bacon in the early 17th century. Also some aspects can be found in the pragmatist tradition. Today Hacking (1996), Latour and Woolgar (1979) argue for this position: Here, a severe debate between Latour ("realcontructivism") and the Edinburgh School of Constructivism ("social constructivism" , David Bloor et al.).

[16] Further: Erich Jantsch (1980) views self organization theory as a unification approach with multidimensional "scientific and human implications". Klaus Mainzer (1996) identifies within the complex systems theory "the basic principles of a common systems science in the 21st century, overcoming traditional boundaries between natural, cognitive, and social sciences, mathematics, humanities and philosophy."

[17] It addresses old questions of the emergence of *new* phenomena, of *new* properties, patterns, entities, and qualities. One important lesson of complex systems theory for all sciences is the fundamental role of instability in nature, technology and even in social processes.

[18] In other branches it is clear that hermeneutics is not reducible to empirical measurement and quantitative objectivity; empirical measurement and data analysis methodologies are not reducible to hermeneutics.

[19] "Nature", the protagonists of Bionics are concerned, "reaches its goals efficiently and economically, with a minimum of available energy and resources. The experience available in Nature can be applied to conduct technological research and development." (Hill 1998)

[20] Construction and reconstruction, intervention and representation, here: technology/engineering science and biology are merged, at least to some degree. Bionics not only aims to produce knowledge but to produce technical artifacts. Analogies play an important methodological role. So, bionics turns out to be an outstanding paradigm of a *technoscience* that is based on a transfer method across the *border or trading zone* (Galison 1996) between biology and engineering.

[21] For course, social scientists have mainly focused on this point-but neglected other, more "internal" elements. – Until now it is unclear what the basic criteria are to specify anything as a "problem". The term "problem" remains an unspecified label. A "philosophy of problems" has not been developed until now. However, regarding "interdisciplinarity" a demarcation is assumed to exist. "Interdisciplinarity" considers that their problems are science-*external*, societal pressing, and policy relevant. Obviously, sciences (= societal-*external* = sciences-*internal*) are regarded from the perspective of society (= science-*external* = societal-*internal*). See Cozzens/Gieryn (1990).

[22] Usually a distinction is presupposed between science-*internal* and science-*external* problems; this traces back to heated debates in the philosophy of science on internalism and externalism (cp. Böhme et al. 1974).

[23] However, in addition, the motives could also be very strict driven from industry and economy. "Real world" economic problems do not fit in the historically grown functional differentiation and separation of academic disciplines. Often,

disciplinary knowledge cannot be applied to the pursuit of economic goals; its utility for the "real economic world" is very limited. Economic "practices" and "applications" are regarded as being themselves "interdisciplinary",

[24] This question should not be addressed here. F.i. realists argue generally in favor of interdisciplinarity from another perspective than rationalists, methodological constructivist, pragmatists or utilitarists.

[25] In addition, when emphasizing "the mathematics of complex systems" (Roco/Bainbridge 2002, x) the NBIC-advocates should be aware that this theory is developed in the framework of mathematical physics in the last 40 years, and it traces back to Hénri Poincaré and George David Birkhoff. Complex systems theory is based on deterministic equations that are hardly applied to individual action, social behavior and political decision making. Such an approach would provide an "unified cause-and-effect understanding of the physical world from the nanoscale to the planetary scale." (Roco/Bainbridge 2002, x) However, complex systems theory might be applied to what has to be considered as the technoscientific core of the NBIC-scenario: the technologies themselves and engineering technosciences in particular. Such an application is neither new nor unique; history is full of examples. By this, I do not follow George Khushf who identifies a system theoretic thinking by the NBIC-visionaries (Khushf 2004). Now, besides complex systems theory it is hard to identify any other interdisciplinary theory or concept that might fit to "Convergence Technologies".

[26] Not everything that is realconstructed is supposed to be interdisciplinary. Classical objects like a machine tool is located in the domain of mechanical engineering.

[27] If the NBIC-scenario would be more broad, f.i. cognitive sciences are not just regarded as natural (cognitive) sciences with cause-and-effect-explanations and the controlling aim, then we would have to include the mind-brain-object. This object is a perfect example of a universal object-interdisciplinarity. However, the NBIC-advocates do not seem to go that far.

[28] If we go further, we may add that it is doubtful whether we can find a meaningful understanding of interdisciplinarity in the NBIC-scenario. The NBIC-advocates eliminate the tension between reductionism and anti-reductionism that is essential for a meaningful understanding of interdisciplinarity. They mainly argue in favor of a technoscientific reductionism which is based on the metaphysical understanding of a unity of Nature

[29] After closing our discussion we should also stress: in the frame of the NBIC-scenario there could also be elements of organizational forms of interdisciplinarity. But this is not what was intended by the NBIC-advocates, because, according to them interdisciplinarity "means more than simply coordination of projects and groups talking to one another along the way." (Roco/Bainbridge 2002, 32)

[30] And, Immanuel Kant linked the manipulation and construction of nature on the one hand with understanding on the other hand: We understand nature only as far as we can constitute and construct her! (Kant 1989, 25f)

[31] Representing and intervening are, as stated by Hacking, twin sisters (Hacking 1996). Science and modern technology have always been merged as *technosciences* (see: Latour 1987; Haraway 1995; Nordmann 2004). The *more* one knows about nature in the scope of a science-based reductionist methodology, the *more effectively* one can act, intervene, and manipulate.

[32] But, it remains a political issue whether we should accept the dissolution of our cultural distinctions. Normative and ethical questions continue to emerge within this new type of knowledge politics such as NBIC-politics (similar: nature-politics, bio-politics) which should be critically taken into account ...

[33] The European Commission drew attention to CTs in the middle of 2003 issue of the *Foresighting Europe* newsletter. It featured a report about two NBIC conferences in the US that considered *Converging Technologies for the Improvement of Human Performance*. The newsletter's editorial continued: "In order to deal with the questions developed in the US NBIC report, the Commission envisages the establishment of a high level expert group on Converging Technologies."

[34] The report says further: "CTs converge on common goals or shared visions, and first among the opportunities and challenges is the formulation of such goals." (Nordmann et al. 2004, 4)

[35] In addition: „(8.) A permanent societal observatory should be established for real-time monitoring and assessment of international CT research, including C*TEKS*. (9.) That the Commission implement a "EuroSpecs" research process for the development of European design specifications for converging technologies, dealing with normative issues in preparation of an international "code of good conduct." (10.) The integration of social research into CT development should be promoted through *Begleitforschung* ("accompanying research" alongside science and technology R&D)." (Nordmann et al. 2004, 5)

[36] And, we might add another question, Is it still reasonable to continue talking about "interdisciplinarity" with regard to (techno-) objects?